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Responses of soil Cryptostigmata across the boundary between a farm woodland and an arable field

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Summary. In a short transect across the boundary of a farm Woodland in the Vale of York (UK), cryptostigmatic mite populations and community organization exhibited sharp changes. Most species were restricted to the woodland or to specific zones within the woodland. Only a few species were recorded in the arable field, and these were generally represented by only a few individuals. Thus, most populations appear to be isolated in the woodland fragment and are surrounded by a hostile arable environment.

Key words: Cryptostigmata, Farm woodland, short transect, ordination, fuzzy clustering

Introduction

Farm woodlands, established for the protection of soil and for game birds, form a mosaic in the agricultural landscape; from the point of view of most invertebrate animals each woodland is more or less isolated. Thus, they represent a good, although not typical, example of a fragmented habitat. Typically, habitat fragmentation is associated with development and especially with the extension of various agricultural and silvicultural practices. In the case of farm woodlands, however, the otherwise uniform agricultural landscape was fragmented by the development of small plantations and of an extensive network of hedgerows. In either case, the consequences seem to be the same; small populations are more or less isolated in each fragment and the risk of local extinction is increased accordingly, due to deterministic, demographic, genetic or stochastic effects. Farm woodlands represent a large scale experiment of species colonizations and extinctions, and hence applied aspects of island biogeography.

Farm woodlands can be used to address a number of significant ecological questions (e.g. Usher et al. 1992). Do they act as "islands" for woodland species in an otherwise hostile environment? Are they the final refuges for these species, or do they act as foci from which the arable fields are or can be recolonized? The aim of this paper is to describe the dynamics of soil Cryptostigmata populations at the woodland boundary. Sharp environmental gradients are likely to have been established across the abrupt field-woodland transition. The sharpness of the changes in population densities and community structure imposed by such a gradient can be used as a measure of the degree of isolation of the populations.

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Materials and Methods

Field methods and sampling procedure

This study was located in Millfield Plantation (National Grid Reference, Se 643/426, c. 10 km south of York, U.K. The wood is long, thin, L-shaped, 3.7 ha in area, planted in 1920, and is a mixed deciduous and coniferous woodland with a dense elder *(Sambucus nigra)* understorey (see Fig. 1a). Data on the crops grown in the field adjacent to the woodland and the biocides applied during 1991 are shown in Table 1. The sampling site was a 60 × 10 m rectangular plot, with the long axis starting at the centre of the wood (18 m from the boundary) and projecting into the cultivated field (Fig. 1a and b). Nine sampling zones were selected within the plot: one at the margin of the wood (WF zone), four inside the wood W1, W4, W9 and W18) and four (F1, F4, F9 and F40) in the cultivated field (note that, W = Wood, F = Field and the number refers to the distance from the margin in metres). The transect was sampled for soil microarthropods on four occasions, on 16 October 1990, 19 November 1990, 14 February 1991 and 15 April 1991. The sample in February was taken under a snow cover, and in April after two weeks without rain. Five soil cores, each 5 cm in diameter and about 10 cm deep, were taken from each zone. The soil cores were subdivided into upper and lower 5-cm layers and stored in labelled polythene bags. The animals were extracted by a high gradient (modified MacFadyen) extractor. The extractions lasted for a week, during which the temperature was increased successively from 10 to 40 °C. The microarthropods were collected in 15% ethanol, transferred to Petri dishes and stored in the refrigerator (2 °C), to prevent fungal growth, until they were stored under a stereomicroscope. All oppiids and immature stages of Cryptostigmata, and large samples of other mature Cryptostigmata, were subsequently treated in lactic acid and examined under a compound microscope for species and instar identification. Analysis of organochlorine residues was performed at the Institute of Terrestrial Ecology (Monks Wood Experimental Station), using 50 g of soil from each sampling zone.

Table 1. Crops produced in the field during the last six years and biocides used during 1990/91. The data were supplied by the farm manager

Year	Crop	Biocides	ml/ha
1986	Oil seed rape	October 1990	
1987	Winter wheat	Clorotoluran	7.0
1988	Winter barley	Cypermetrin	0.25
1989	Winter wheat	April 1991	
1990	Winter wheat	Flusilazole	0.4
1991	Winter barley	Fluroxypyr	0.5
		Mecoprop-P	2.0
		Chlorothalanil + Fenpropimorph	0.4

Data analysis

Species diversity was estimated by the Shannon-Weaver formula. Detrended correspondence analysis (Hill & Gauch 1980) using a polynomial detrending method (ter Braak 1988) was used on logarithmically transformed data for the analysis of microarthropod responses along the transect. A fuzzy k-means clustering method (Equihua 1990) was also used to separate groups of samples over the ordination field. In this method samples are given degrees of membership to all the clusters. The membership values range from 0 to 1 and sum up to 1. Thus, the boundaries of the clusters are no well defined as in ordinary classification methods, that is the groups produced are not mutually exclusive. The method can be used to approach both the concept of communities as recognizable entities, and the concept of species composition changing along a continuum (Equihua 1990).

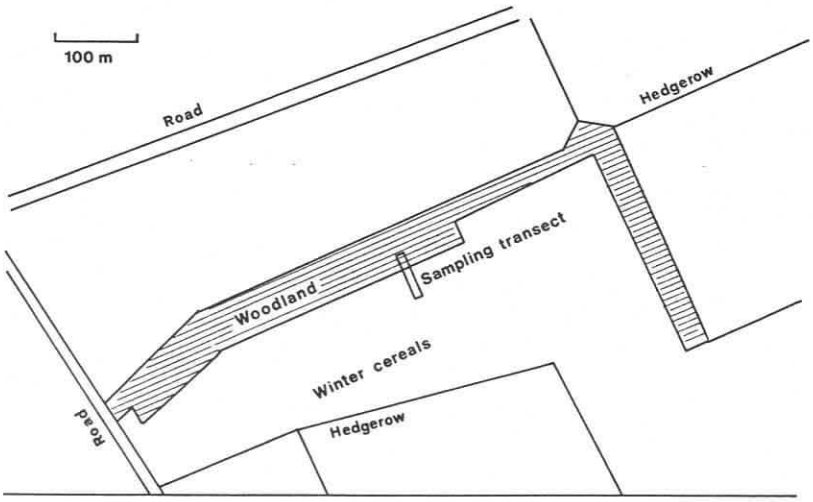


Fig. 1a

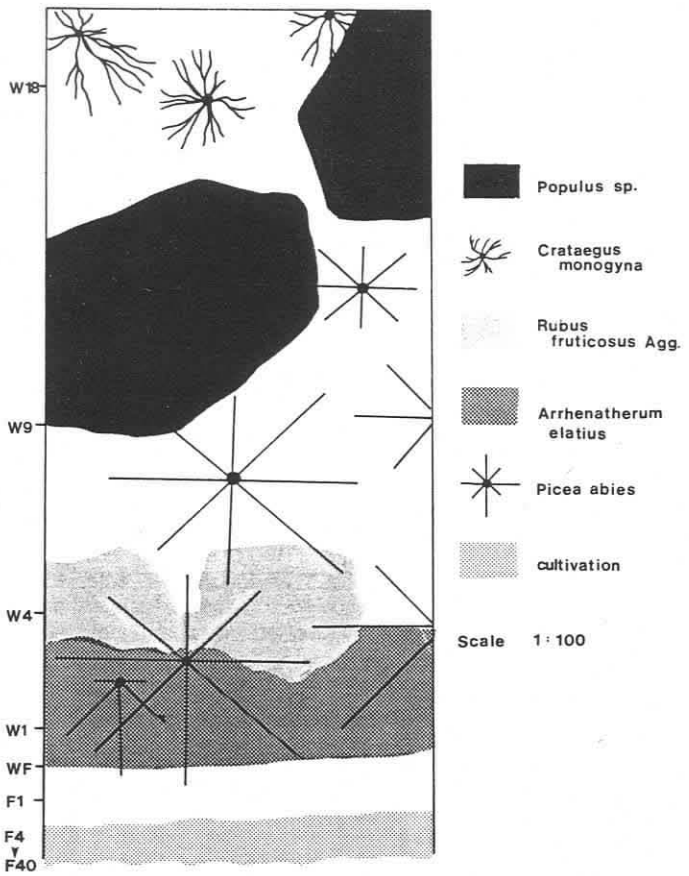


Fig. 1b

Fig. 1. Plan illustrating the woodland and surrounding area (a) and part of the transect sampled (b) showing the distribution of plant species within the woodland. Due to its uniformity most of the field transect is omitted

Results

Transect characteristics

In Table 2 data on the vegetation, litter and soil of the transect are shown. There were differences between zones regarding the overstorey and understorey vegetation, the structure of the litter layer and soil pH. The innermost woodland zone (W18) was the deciduous and the outer (W9 to W1) the coniferous part of the transect (Fig. 1b). Inside the woodland the understorey vegetation was formed by *S. nigra* but at the margins it was replaced by *Rubus fruticosus* agg. and *Arrenatherum elatius*. Soil pH differed between the woodland (acid) and the field soil (almost neutral) as expected. The soil had no organochlorine residues. This indicates that organochloride biocides had not been used in the area during the previous twenty years (Davis, personal communication).

Table 2. Vegetation, litter composition and soil pH of the woodland (W) and the field (F) transect. The zones are described in the text

	Zone W18	W9	W4	W1	WF	F1	F4	F9	F40
Distance from margin (m).	18	9	4	1	0	1	4	9	40
Overstorey plant species	*Crataegus monogyna*	*Picea abies* *Populus* sp.	*Picea abies*	*Picea abies*	–	–	–	–	–
Understorey plant species	Dense *Sambucus nigra*		*Rubus fruticosus* agg.		*Arrhenatherum elatius*		Bare soil	Winter cereals	
Leaf litter	Thick layer *P. abies* litter. Thin layer *Populus* and *Quercus robur* leaves at surface.		*A. elatius* litter			Scattered *Populus* litter			
Soil pH	4.5	4.3	4.3	4.8	4.6	6.1	7.2	7.1	6.3

Population densities of Cryptostigmata

The mean population densities of Cryptostigmata in each sampling zone are shown in Table 3. With the marked exception of *P. punctum*, Cryptostigmata were scarcely found in the field while they were abundant in the woodland. The field zones were inhabited mostly by Collembola (especially *Folsomia quadrioculata* and *Onychiurus armatus*) and Prostigmata. The variations in number of species, diversity and population density of Cryptostigmata are shown in Fig. 2. Maximum values of all three measures were recorded in the woodland and minimum values in the field zones while the transition zone between the two was associated with a sharp decline of both diversity and number of species. It is also noted that the absolute maximum species diversity was recorded in the marginal (W1) zone. Temporal variations in population density of some abundant species are shown in Fig. 3. The response surfaces graphed outline four main types of temporal patterns followed by most species (Table 4).

Table 3. Mean population density* (ind./core) soil Cryptostigmata along the transect. For site codes see Table 2. Species names follow M. Luxton, *The Oribatid Mites of the British Isles* (in prep.)

	Sampling zone						
	W18	W9	W4	W1	WF	F1	F4–
Medioppia subpectinata (Oudemans, 1900)	15	+	–	–	–	–	–
Ceratoppia bipilis (Hermann, 1804)	3	+	+	–	+	–	–
C. bipilis (juv.)	3	1	+	+	–	–	–
Adoristes poppei (Oudemans, 1906)	+	+	+	+	–	–	–
Carabodes labyrinthicus (Michael, 1879)	1	1	+	+	+	–	–
Phthiracarus spp. *(2 species)*	2	2	1	1	+	–	–
Quadroppia quadricarinata (Michael, 1885)	7	1	3	2	+	–	–
Autogneta longilamellata (Michael, 1885)	6	–	–	+	–	–	–
Hermannia scabra (C. L. Koch, 1879)	–	2	1	–	–	–	–
H. scabra (juv.)	+	7	3	+	–	–	–
Nothrus palustris (C. L. Koch, 1839)	1	+	+	+	–	–	–
N. palustris (juv.)	4	1	1	1	+	–	–
Suctobelba trigona (Michael, 1888)	+	+	–	+	+	–	–
Suctobelbella subtrigona (Oudemans, 1900)	+	+	+	+	–	–	–
Suctobelbella subcornigera (Forsslund, 1941)	14	10	15	9	1	–	–
Liacarus coracinus (C. L. Koch, 1839)	1	+	1	1	–	–	–
Liochthonius sp.	+	3	2	+	–	–	–
Tectocepheus velatus (Michael, 1880)	19	25	21	1	3	1	+
T. velatus (juv.)	28	89	45	1	4	+	+
Brachychthonius sp.	–	+	1	1	–	–	–
Oppiella nova (Oudemans, 1902)	30	3	1	1	1	+	+
Oribatula tibialis (Nicolet, 1855)	+	9	5	4	+	+	+
Xenillus tegeocranus (Hermann, 1804)	2	1	1	1	1	–	–
Galumna lanceata (Oudemans, 1900)	1	+	+	1	–	–	–
Dissorhina ornata (Oudemans, 1900)	9	5	10	9	1	–	–
Platynothrus peltifer (C. L. Koch, 1839)	2	+	1	2	+	–	–
P. peltifer (juv.)	2	+	1	4	+	–	–
Euzetes nitens (Johnston, 1853)	+	+	1	2	+	–	–
Damaeus (Adamaeus) onustus (C. L. Koch, 1841)	1	+	+	1	1	–	–
D. onustus (juv.)	+	+	+	1	+	–	–
Microppia minus (Paoli, 1908)	1	+	5	4	1	–	–
Banksinoma lanceolata (Michael, 1885)	+	–	–	–	–	+	–
Ceratozetes mediocris (Berlese, 1908)	1	+	+	+	3	–	–
C. mediocris (juv.)	2	+	+	3	5	+	–
Eupelops plicatus (C. L. Koch 1835)	1	+	+	+	+	–	–
Oribatella quadricornuta (Michael, 1880)	+	+	11	6	5	+	–
Punctoribates punctum (C. L. Koch, 1839)	1	1	1	5	33	1	5
Metabelba papillipes (Nicolet, 1855)	–	–	+	5	4	+	–
M. papillipes (juv.)	–	–	+	5	5	+	–
Liebstadia similis (Michael, 1888)	–	–	+	8	10	+	–
Insculptoppia clavipectinata (Michael, 1885)	–	–	+	11	17	1	+
Latilamellobates incisellus (Kramer, 1897)	–	+	–	+	2	+	–

Other species: *Chamobates cuspidatus* (Michael, 1884), *Cepheus dentatus* (Michael, 1888), *Atropacarus striculus* (C. L. Koch, 1835), *Damaeus clavipes* (Hermann, 1804)

* Values are rounded to the nearest integer. Values less than 0.5 are indicated by + and absence by – symbols

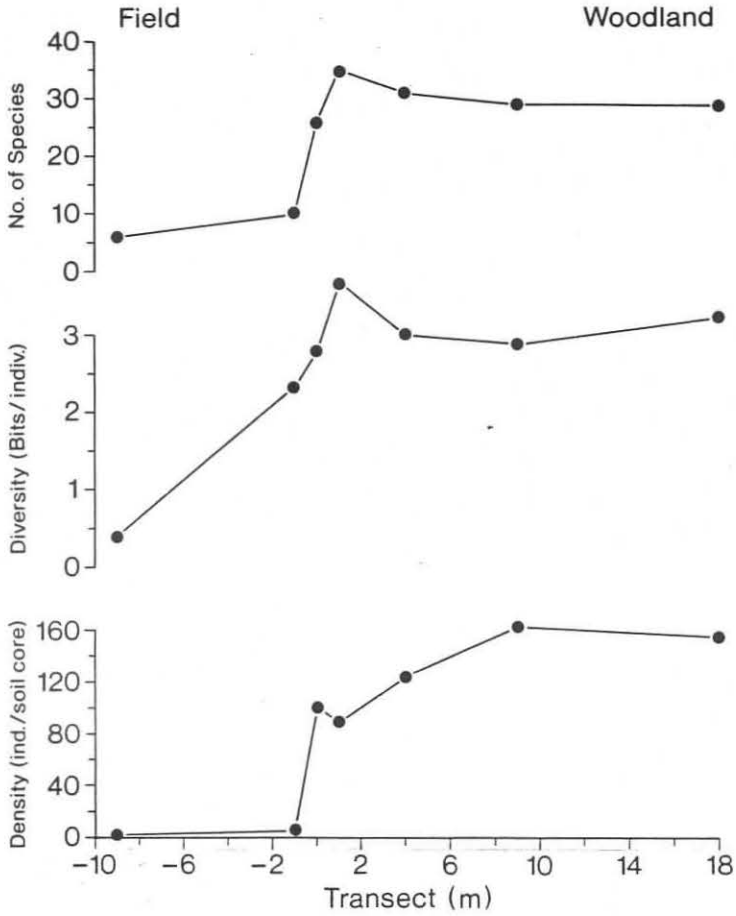


Fig. 2. Variation in number of species, species diversity and population density of Cryptostigmata along the transect

First, *C. bipilis* adults (Fig. 3a) were recorded mainly in late winter and spring in the deciduous part of the woodland. The main period of ontogenetic development appeared to be winter although larvae were recorded throughout the sampling period in quite stable population density.

Second, *T. velatus* (Fig. 3b, c) dominated the cryptostigmatic mite fauna in the coniferous part of the wood (W9). The subpopulation of adults (Fig. 3b) was widely distributed over the woodland part of the transect in October 1990. However, the maximum number of juveniles produced by these adults was at the W9 site (Fig. 3c). Thus, a possible second generation of adults appeared to inhabit mainly the W9 site in April. The same holds for what appeared to be a second generation of juveniles during the period from February to April. Although this species exhibited two density peaks during the study period, all the developmental stages were present in all samples and onotgenetic development was probably continuous throughout the study period.

Third, *M. papillipes* adults (Fig. 3d) were restricted to the marginal zone and their abundance increased progressively towards spring. Winter was its main period of ontogenetic development (Fig. 3e).

Fourth, *Q. quadricarinata* adults (Fig. 3f) were widely distributed throughout the woodland, but peak densities were recorded in the W18 and W4 zones during autumn and spring.

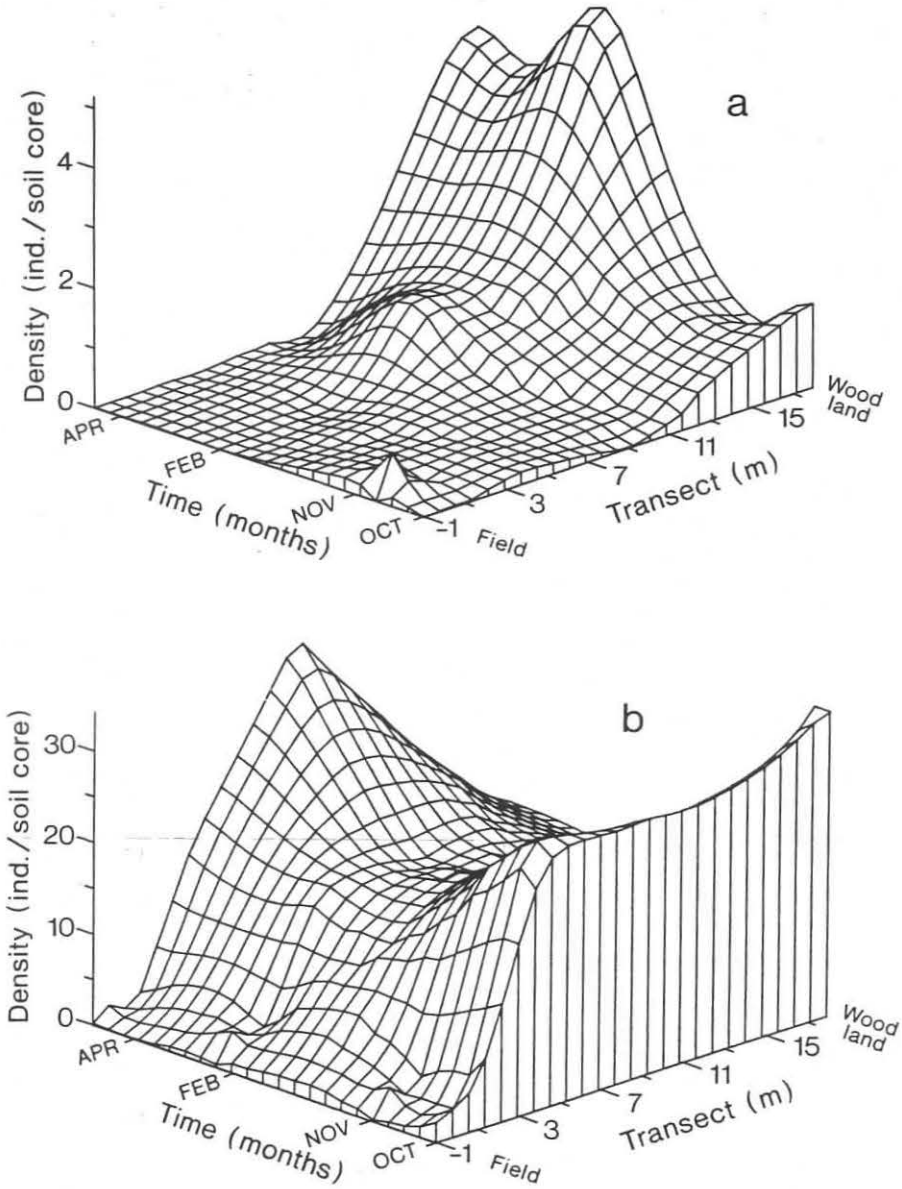
Table 4. Four categories of Cryptostigmata distribution and abundance along the transect

	Category	Species	Comments
I.	Inhabitants of deciduous zone (W18)	*C. bipilis* *A. poppei* *O. nova* *M. subpectinata*	Abundance increased progressively towards spring
II.	Inhabitants of coniferous zone (W9–W14)	*T. velatus* *O. tibialis* *C. labyrinthicus* *G. lanceata*	Species abundant at W9 but broadly distributed in woodland
III.	Inhabitants of marginal zone	*M. papillipes* *L. similis* *L. incisellus* *O. quadricornuta* *I. clavipectinata* *E. nitens* *P. punctum*	Species more or less restricted to margin. Some also inhabit F1. *P. punctum* also abundant at F40
IV.	Species with bimodal distribution	*Q. quadricarinata* *P. peltifer* *S. subcornigera* *C. mediocris* *Damaeus* spp. *D. ornata*	Bimodal mostly during spring, possibly due to high density of *T. velatus* at W9

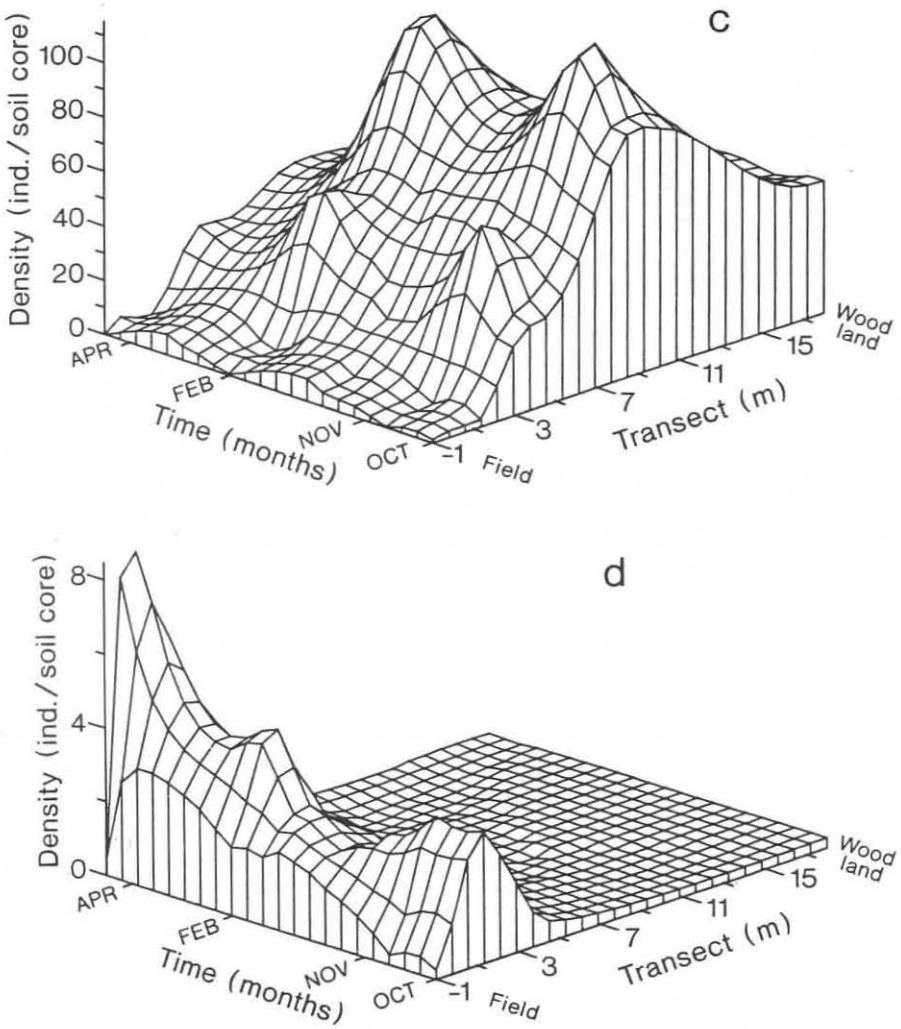
Community changes along the transect

The ordination of Cryptostigmata is shown in Fig. 4. The main gradient represents the transition from the inner woodland towards the margin and the field zones. It is a long gradient (3.5 SD, *sensu* Hill & Gauch 1980), due to the high rate of species replacements characterizing the transition from the W4 to W1 zones. The second axis accounts mainly for the distinction between the deciduous (W18) and coniferous zones as well as the partial distinction of the field zones (F) from the margin (WF). The seasonal changes and the variation among replicates of each sampling zone are also depicted in the two axes plane. The seasonal trend concerning the inner woodland sites is represented as a linear shift on the second axis with an up to down direction regarding W4 and W18 sites and the opposite regarding the W9 site. This is associated mainly with the observed tendency of *T. velatus* and *O. tibialis* to aggregate in the W9 zone, together with the dispersion of *Q. quadricarinata* and *D. ornata* towards the W4 and W18 zones through time. At the margin, the seasonal effect is represented as an almost cyclic shift of low magnitude.

The classification of the sample units is shown in Fig. 5. The best partition of the sample space is obtained for five fuzzy groups. The value of a fuzzy classification is that it produces partitions of the sampling plot giving some details on the spatial overlap of the species assemblages along the transect (samples of different zones are members of the same group) as well as on the overlap of the groups themselves as expected from a fuzzy classification method. Group I is rather homogeneous as it mainly includes the samples of the deciduous zone (W18). However, it shares 2 samples of W9 with group II (characterized by a relatively high abundance of *Phthiracarus* spp.) and one sample with groups II and III, due to the evenly distributed *X. tegeocranus* in the inner woodland zones. Group II includes most



samples of the W9 and W4 zones where *T. velatus* and *O. tibialis* are the dominant species. Groups IV and V contain samples of the W1, WF and F zones. Group IV includes mainly samples of the WF zone, characterized by a rather rich species assemblage, while group V contains the samples of the field zones characterized by the dominance of *P. punctum*. Finally, the most important point is the composition of group III which overlap with all the other groups except group V. In fact, group III represents a transition zone where elements of the inner woodland and marginal fauna meet. This transition zone (W1 and part of W4) is characterized by the highest species richness and diversity and the lowest dominance index of the Cryptostigmata community.



Discussion

Thirty nine species of Cryptostigmata (including some that are very rare) were recorded in the study plot. Only ten species were found in the arable field and among them only *P. punctum* was recorded frequently and in large numbers. Most of the others were restricted to the narrow unvegetated F1 zone and were represented by only a few individuals. The latter observation might imply that there was a dispersion tendency by some species inhabiting the margin, but equally that they were hardly able to establish a good population in the field.

The low representattion of Cryptostigmata in arable fields has been reported by Emmanuel et al. (1985), Lagerlof & Andren (1988), Curry & Momen (1988) and Nakamura (1989), while the ability of *P. punctum* to persist in cultivated soil has been reported by Sheals (1956). On the other hand, Wasylik (1989) reported that Cryptostigmata, among them *T. velatus*, was the most abundant group among the Acari in a wheat field in Poland, rich in organic matter and with a soil pH of 5.5.

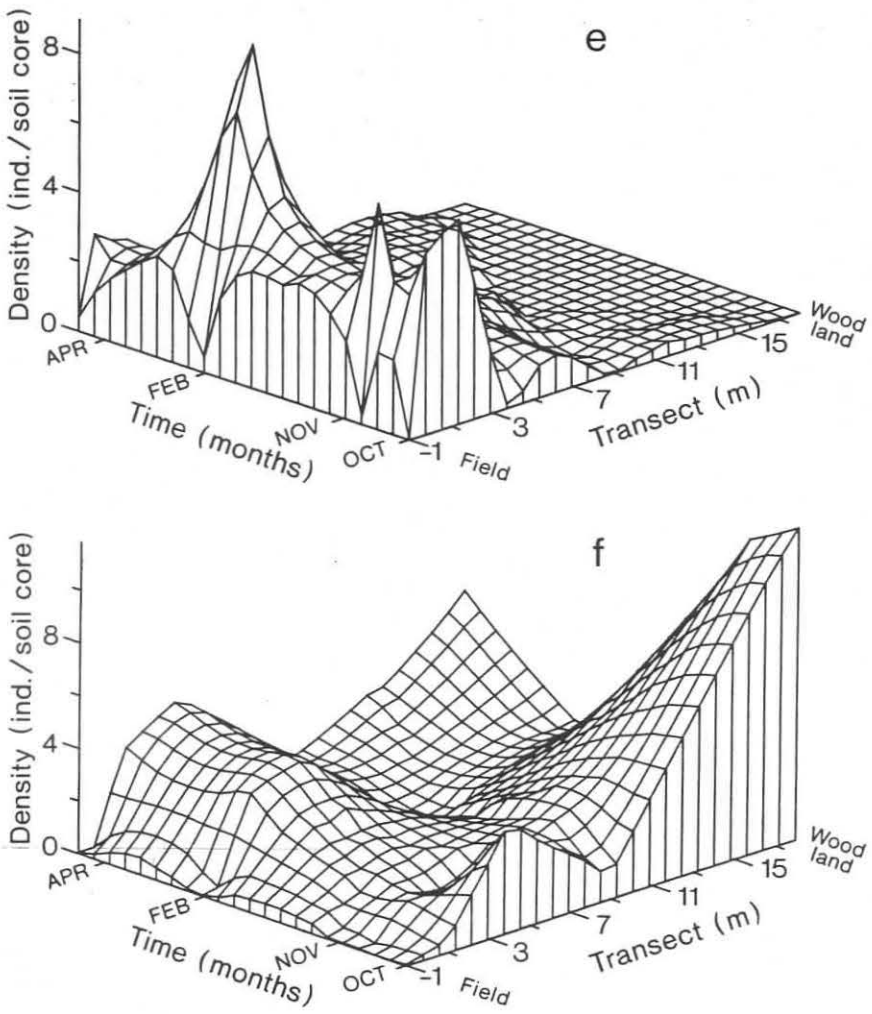


Fig. 3. Spatial and temporal variations in population density of Cryptostigmata along the transect for four sampling dates: **a)** *C. bipilis* adults. **b)** *T. velatus* adults. **c)** *T. velatus* juveniles. **d)** *M. papillipes* adults. **e)** *M. papillipes* juveniles. **f)** *Q. quadricarinata* adults

Ploughing and the application of biocides and inorganic fertilizers are considered to be the main causes affecting survival and reproducttion of soil microarthopods in arable fields (Moore et al. 1984, Mallow et al. 1985, Andren & Lagerlof 1983). The complicated effects of repeated agricultural disturbance (inversion of the upper soil layers, reduction of vegetation cover, microclimate changes) could be combined into to a single variable; the period available for soil animal populations to grow is shortened. This would favour r- and some A-selected species (Greenslade 1983), such as some of the Collembola and Prostigmata (see for example Curry & Momen 1988, Andren & Lagerlof 1983 and also the reclamation experiment of Petersen & Gjelstrup 1985). On the other hand, such a permanently disturbed environment is hostile to most soil Cryptostigmata species which are characterized by a long life span and ontogenetic development, low fecundity, relatively poor dispersion ability and a kind of parental care regarding oviposition microsites (Jalil 1965, Lebrun 1970, Webb 1977, Weigmann 1979, Murphy & Jalil 1964, Bellido 1990, Steinberger et al. 1990, Stamou & Asikidis 1992).

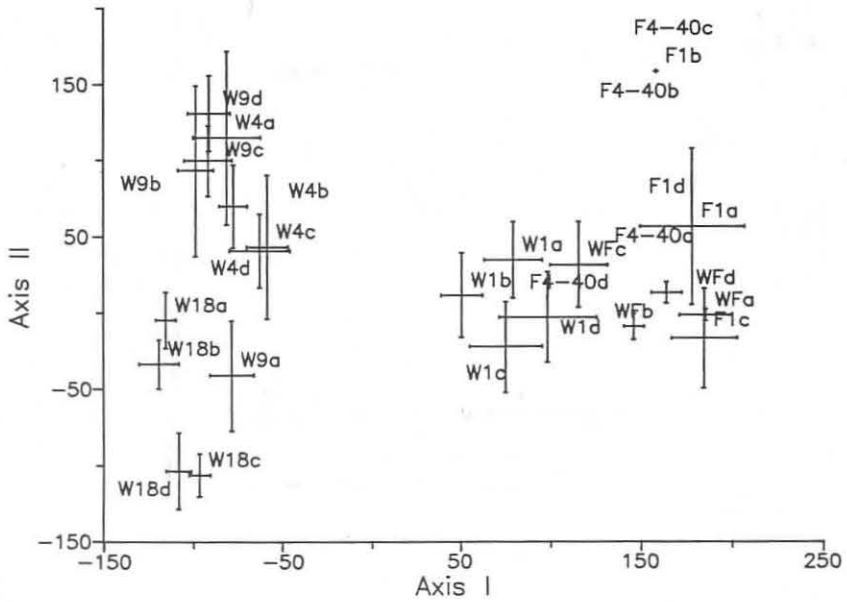


Fig. 4. Ordination of the sample units by detrended correspondence analysis. Codes: zone names as in Table 2. a–d sampling dates (a = 16 October, b = 19 November, c = 14 February, d = 15 April). The intersection of each pair of bars represents the mean and the bars the variation (standard errors) of the scores of the replicates (N = 5) of each zone and sampling date. The eigenvalues of the first two axes are 0.53 and 0.17 respectively

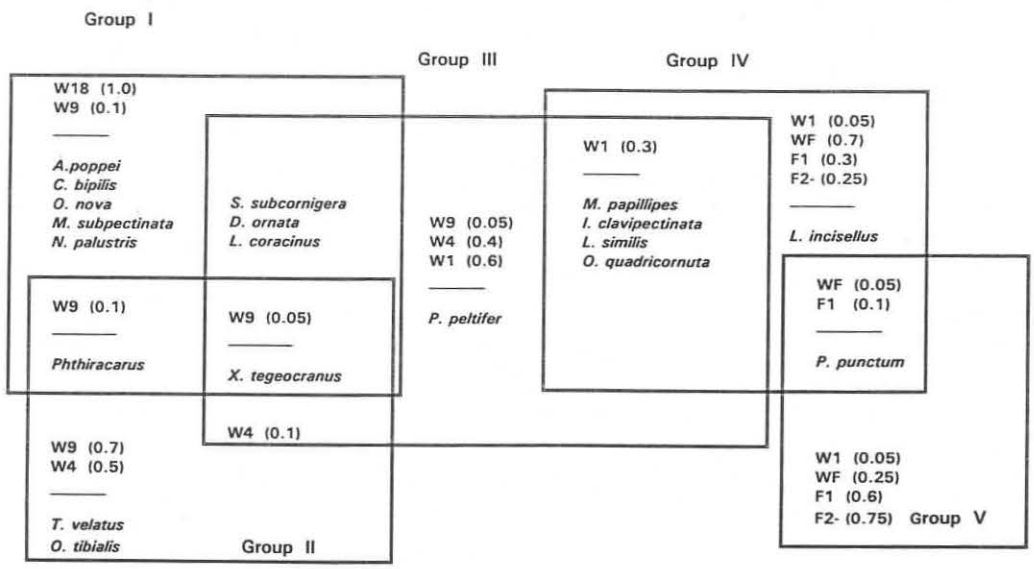


Fig. 5. Fuzzy classification of the sample units and of the characteristic species. The number of the sample units of each zone belonging to a group, as a fraction of the total number (20 units) is given in parentheses

Due to their demographic characteristics and food preferences, Cryptostigmata are common inhabitants of the upper soil layers and especially of the litter of stable soils (Pande & Berthet 1975, Usher 1975) and their diversity is related to the structural diversity of the upper soil they inhabit (Anderson 1978). Thus, the observed distribution pattern of Cryptostigmata along the woodland part of the transect is possibly imposed by the differences in structural and microclimate characteristics of the litter layer between zones and especially between the inner woodland and the marginal zones (see Table 2). Considering especially the marginal zone it is possible to hypothesize a rhizosphere effect on Cryptostigmata populations like the one observed by Stamou (1981) in a temperate woodland. A pesticide spray effect, assuming differential tolerances of different species, is not to be excluded although there is no evidence for that.

Sharp gradients, imposing considerable changes of Cryptostigmata community organization along short distances, have been also found by Asikidis & Stamou (1991) inside clusters of *Quercus coccifera* shrubs in a Mediterranean type formation, and by Schenker (1984) in a mixed temperate forest. In the latter casee, Cryptostigmata were found to form large aggregations of up to several meters in diameter around specific trees. The observation that several Cryptostigmata species are localized into specific microsites or zones is consistent with the findings of Usher (1975) concerning the aggregation properties of Cryptostigmata, i.e. the tendency exhibited by most species to increase the number of individuals per aggregation in response to density increase.

Cryptostigmata therefore appear to be restricted in agricultural landscapes largely to small woodland fragments, and even to specific zones inside the fragments. The cryptostigmatic fauna inhabiting the woodland today could be considered to be a mixture of the pre-woodland fauna of the area, with some species introduced along with the roots of the trees planted, and possibly other species colonizing the area. The marginal zone of the woodland may be a remnant of the pre-woodland vegetation of the area and hence this may also be true for some of the invertebrate species inhabiting it. This zone is also connected to the hedgerows, and in some places it is itself a hedgerow. The hedgerow network is known to be serving as a corridor facilitating dispersion of various species of small mammals (Zhang & Usher 1992), but little is yet known about the importance of hedgerows for invertebrates (but see Jones 1992).

Conclusions

There are two main conclusions that can be drawn from this study.

1. The woodland-field boundary seems to be a real barrier for the dispersal of most Cryptostigmata species. This can be explained demographically in relation to the short period available between disturbances for population growth in the arable field.

2. There is a distinct Cryptostigmata species assemblage inhabiting the narrow marginal zone of the woodland. A reasonable, but not yet tested hypothesis, is that this is a remnant of the pre-woodland fauna of the area, restricted to this zone after the introduction of a new fauna associated with the trees planted 70 years ago. In any case, the marginal zone is of significance as it seems to have a great contribution in maintaining the diversity of Cryptostigmata within an agricultural landscape of arable fields, small farm woodlands and hedgerows.

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